DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
(ADVANCED RESEARCH PROJECT AGENCY)

Contract Nonr 1858(32) - NR 098-201

# BURNING RATE CONTROL FACTORS IN SOLID PROPELLANTS

## Third Quarterly Status Report

For the Period 1 July 1959 to 30 September 1959

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Prepared by: Kimball P. Hall
Kimball P. Hall
Research Associate

and E. Karl Bastress
E. Karl Bastress
Research Assistant

Approved by: Kimball P. Hall
for Martin Summerfield
Principal Investigator

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Department of Aeronautical Engineering
PRINCETON UNIVERSITY
Princeton, New Jersey

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## I. INTRODUCTION

This report describes progress during the third quarter of a research program directed at studies of mechanisms and control factors of steady state burning of composite solid propellants. The specific aims of the program and its status as of April 1 of this year were outlined in Reference 1.

Research topics which are discussed in this quarterly report include: (1) Study of the effect of acoustic stirring upon the burning process, (2) Status of the problems of oxidizer particle size measurement and of an oxidizer particle "sizing" technique, and (3) Measurement of burning rates in rocket motors.

Action toward construction of an improved processing facility progressed as follows during this 3 month period: ARPA transferred funds to ONR for this purpose; active negotiation on contract terms was entered into between ONR and Princeton University.

## II. EFFECTS OF ACOUSTIC STIRRING ON BURNING RATE

Five revisions have been made in the configuration and/or operating procedure of the rocket motor used for investigation the effects of acoustic energy; namely: (1) A system for quenching and extinguishing the propellant during a motor test has been put into operation (See Figure 1), (2) The restricter plug has been omitted from the forward end of the grain*, (3) Nitrogen is now used instead of air as the gas to excite the acoustic whistle, (4) Provision has been made for continuously varying the whistle configuration during the course of a motor test, (5) A water-cooled Kistler piezo-electric pressure transducer has been introduced through the side wall of the whistle "horn" to permit detection of high frequency pressure oscillations during motor firings.

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*The revised configuration consists, typically, of a 5-inch OD, 4-inch long case-bonded polysulfide perchlorate grain with a 2-inch ID perforation, restricted at the nozzle end, but free to burn on both the internal surface and the front end. It is ignited with a 13-gram jellyroll igniter located in the perforation. See Reference 1.

The first three changes were designed to improve our confidence in the experimental results (the second also simplified the interpretation of the data by greatly reducing the progressivity of the pressure-time curve). The purpose of the fourth was to enable the whistle to present to the burning grain a systematically varying range of frequencies, in case mixing should prove effective only in certain restricted frequency regions. The Kistler gauge (Revision #5) was installed to determine whether the acoustic generator was indeed producing high frequency pressure oscillations of reasonable magnitude in the firing motor.

A total of about twenty motors was fired during this quarter, about four with whistle inoperative, the balance with whistle operating. An oscilloscope display of the Kistler output during four tests demonstrated that as the whistle configuration was varied pressure excursions of sizeable amplitude (up to ± 25 psi) and of frequency as high as 15 kilocycles did develop; but none of the pressure-time traces from motors fired with whistle operating differed appreciably from those produced with the whistle inoperative.

We must conclude, therefore, that in these experiments the introduction of acoustic energy did not alter the burning rate of the propellant. We believe that the idea is still worth exploring, but on a more elaborate scale, with better instrumentation.* For the present, this phase of our research will be put aside, to permit greater emphasis on other research objectives.

## III. EFFECTS OF OXIDIZER PARTICLE SIZE ON BURNING RATE

The Mine Safety Appliance Particle Size Analyzer briefly described in Reference 2 has arrived and is receiving preliminary trials for size distribution

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*We suspect that our estimate of the magnitude of input acoustic energy required was too low. (See pp 8 and 9 of Reference 1.)

analysis of ground ammonium perchlorate. More details concerning this equipment will appear in a subsequent report.

The Princeton-designed gravity elutriator described in Reference 1 has been improved as a size classification device for ammonium perchlorate by introducing periodic pulses in the flow of the elutriating gas. These pulses serve to agitate the feed stock bed without altering materially the updraft flow pattern in the elutriator; the output rate of the device is substantially increased. Evaluation of the quality of separation ("sharpness of cut") awaits completion of calibration tests of the MSA analyzer, however.

## IV. BURNING RATE MEASUREMENT IN ROCKET MOTORS

Preliminary motor tests of internal-burning tubular grains produced pressure-time traces that showed excessive tailoff.* To pin down the cause a system for quenching the burning grain prior to burn-out was developed and used successfully to interrupt about twenty firings. (A schematic sketch of the quench system is presented in Figure 1.) Part of the difficulty lay in inadequate deairing of the propellant during casting (as indicated by burned-out bubbles in the interrupted grain); the rest was due to brisant ignition. The technique of slit deairing during casting was improved; and the ignition problem was remedied by substituting a slower acting jellyroll igniter, relocated in the forward end of the motor outside of the perforation. Subsequent pressure-time curves were satisfactory.

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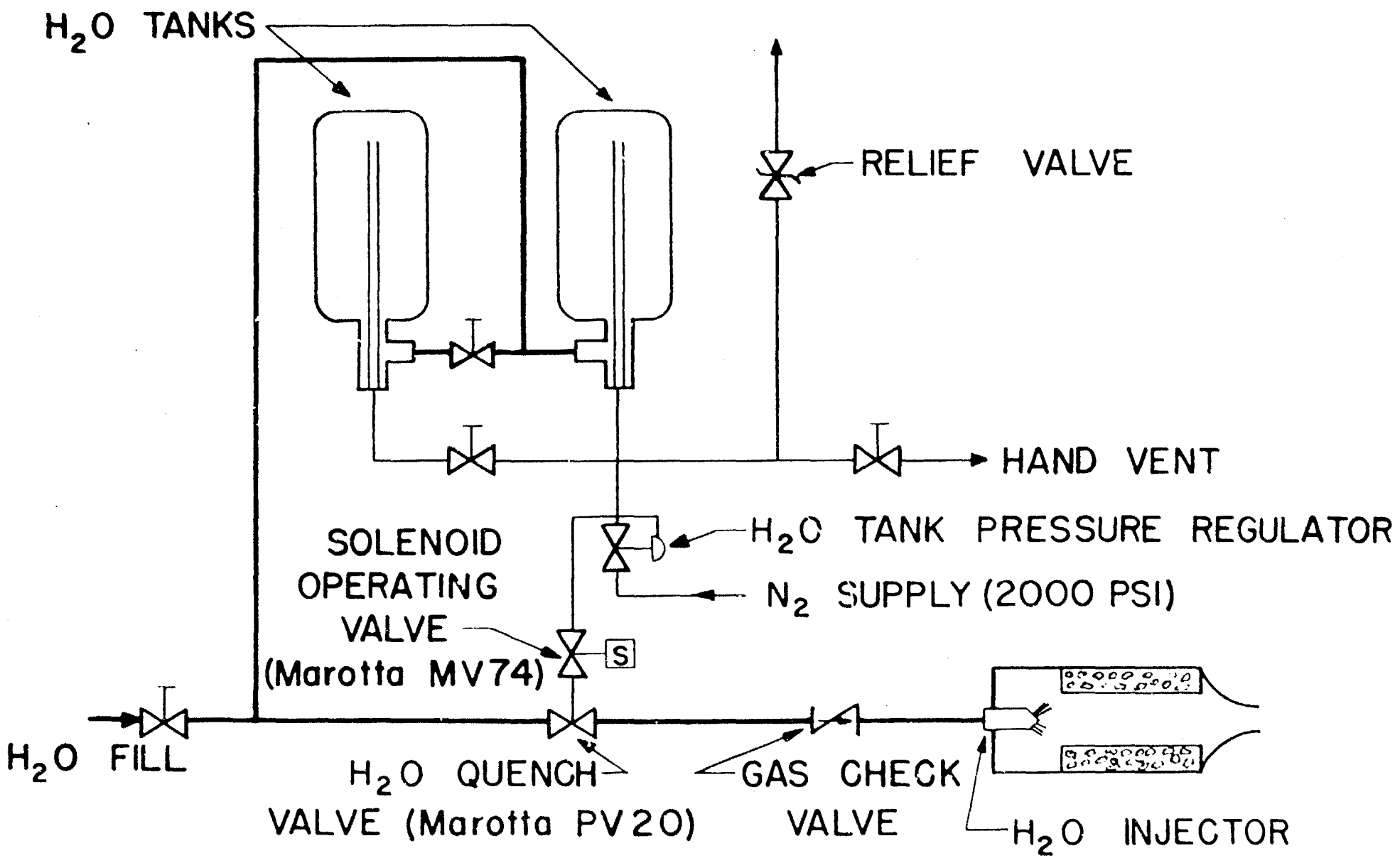
*A typical grain for these experiments was a 1-1/2 inch ID, 3 inch OD cartridge-type, composed of polyesterstyrene perchlorate propellant restricted on its outer diameter and both ends.

# REFERENCES

Initial Progress Report, "Burning Rate Control Factors in Solid Propellants," Aeronautical Engineering Report No. 440-a, Princeton University, 27 April 1959.

Second Quarterly Status Report, "Burning Rate Control Factors in Solid Propellants," Aeronautical Engineering Report No. 440-b, Princeton University, 9 February 1960.

# ROCKET MOTOR COMBUSTION WATER QUENCH SYSTEM



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